RECIPROCATING COMPRESSOR WITH A LINEAR MOTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/394,739 filed July 10, 2002, which Provisional Application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] The present invention is related generally to a mechanical linkage for connecting a linear motor to a piston or pistons of a reciprocating compressor. Specifically, the present invention is directed to a mechanical linkage for a linear motor that defines a travel path for the piston(s).

[0003] A standard refrigeration or heating, ventilation and air conditioning (HVAC) system includes a refrigerant fluid, an evaporator, a compressor, a condenser, and an expansion valve. In a typical refrigeration cycle, the compressor compresses a refrigerant vapor and delivers the vapor to the condenser through a discharge line. The refrigerant vapor delivered to the condenser enters into a heat exchange relationship with another fluid in the condenser and undergoes a phase change to a refrigerant liquid as a result of the heat exchange relationship with the other condenser fluid. The condensed liquid refrigerant from the condenser flows through an expansion valve to the evaporator. The liquid refrigerant in the evaporator enters into a heat exchange relationship with another fluid in the evaporator and undergoes a phase change to a refrigerant vapor as a result of the heat exchange relationship with the other evaporator fluid. The vapor refrigerant in the evaporator exits the evaporator and returns to the compressor by a suction line to complete the cycle. By means of example only, the refrigerant fluid used in the system can be ammonia, ethyl chloride, CFCs, HFCs, Freon®, or other known refrigerants.

[0004] One type of compressor that can be used in a HVAC or refrigeration system is a reciprocating compressor. A linear motor can be used to drive the

reciprocating compressor to improve the efficiency and/or reliability of the compressor. In some applications, linear motors are used with small compressors without positive travel stops for the piston and drive mechanism. However, when the linear motor is connected or attached directly to a piston to compress refrigerant gas, the piston has a tendency to overtravel in light load conditions and undertravel in high load conditions.

[0005] Therefore, what is needed is a mechanism to connect between a linear motor and a piston of reciprocating compressor that can operate as a motion stop for a linear motor, define a positive predetermined piston path at all load conditions and prevent undertravel and overtravel of the piston driver assembly.

SUMMARY OF THE INVENTION

[0006] One embodiment of the present invention is directed to a reciprocating compressor having a linear motor, at least one piston and cylinder arrangement and a mechanism operatively connecting the linear motor to the piston and cylinder arrangement. The piston and cylinder arrangement operates to compress a fluid, preferably a refrigerant gas, and has a cylinder, a piston configured and disposed to travel in the cylinder, and a piston rod connected to the piston. The mechanism connects the linear motor to the piston rod to move the piston in the cylinder upon operation of the linear motor. The mechanism is configured and disposed to limit overtravel of the piston in the cylinder in response to a light load of the reciprocating compressor and to limit undertravel of the piston in the cylinder in response to a heavy load in the reciprocating compressor. The mechanism connecting the linear motor to the piston and cylinder arrangement can include a connecting rod and eccentric, a cam mechanism, a wobble plate mechanism, or a track mechanism, among other things.

[0007] Another embodiment of the present invention is directed to a mechanism for connecting a linear motor to a piston-cylinder arrangement such as in a reciprocating compressor. In this embodiment, the mechanism operates to move the piston in the cylinder upon operation of the linear motor, and includes a mechanical configuration to limit overtravel and undertravel of the piston in the cylinder.

[0008] One advantage of the present invention is that it prevents undertravel and overtravel of the piston driver assembly when a linear motor is used with a reciprocating compressor.

[0009] Another advantage of the present invention is that the piston travels a positive and predetermined path when a linear motor is used with a reciprocating compressor.

[0010] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1 illustrates schematically a first embodiment of a mechanical linkage configuration of the present invention.

[0012] Figure 2 illustrates schematically a second embodiment of a mechanical linkage configuration of the present invention.

[0013] Figure 3 illustrates schematically a third embodiment of a mechanical linkage configuration of the present invention.

[0014] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Figures 1-3 illustrate several embodiments of the present invention. A linear motor 10 is used to drive or move a mechanism that defines the path of the piston or pistons 30 in a reciprocating compressor 40. It is to be understood that the reciprocating compressor 40 includes many other components that are well known in the art which are not shown herein for purposes of simplicity and clarity. The mechanism can be a connecting rod eccentric type mechanism 20 as shown in Figure 1, or the mechanism can be any other type of piston path defining mechanism,

including but not limited to a cam type, gear type, sliding track type, "wobble plate" type or any other suitable piston path defining mechanism. In the embodiments of the present invention, the mechanism controls the path and travel of one or more pistons 30, thereby preventing each piston 30 from overextension during light loads and underextension during heavy loads. Preferably, the mechanism 20 provides a constant predetermined top dead center piston position and bottom dead center piston position to limit or eliminate overtravel and undertravel of the piston 30 in the cylinder 50.

[0016] The reciprocating compressor 40 of the present invention includes one or more cylinders 50. Positioned in each of the cylinder(s) 50 is a piston 30 that can move back and forth in the cylinder 50 in an axial direction. The piston 30 is used to compress a refrigerant gas in the cylinder 50 by traveling toward a closed end of the cylinder 50 to compress the refrigerant gas between the piston face and the closed end of the cylinder. A piston rod 32 is connected to the piston 30 to move the piston 30 in the cylinder 50. The piston rod 32 is connected to a connecting mechanism 20 (see Figure 1), which in turn is connected to the linear motor 10. Preferably, the connecting mechanism 20 also operates to limit movement of the piston rod 32 in the axial direction while moving the piston 30 toward the closed end of the cylinder 50 and while withdrawing the piston 30 from the closed end of the cylinder 50. The operation of the linear motor 10 and connecting mechanism 20 displace the piston rod 32 to move the piston 30 back and forth in the cylinder 50.

[0017] During operation of the linear motor 10, one or more stators 8 drive or move a rotor 12 back and forth in the same axial direction as the piston 30 as shown in Figure 1. Connected to the rotor 12 are one or more connecting linkages 14 that connect the rotor 12 to the connecting mechanism 20. The connecting mechanism 20 shown in Figure 1 is a connecting rod eccentric type mechanism 20 mounted on bearings 21 or other suitable rotating structures using known methods in the art. The movement of the rotor 12 of the linear motor 10 moves the connecting linkages 14, which turn or displace the connecting mechanism 20 thereby moving the piston rod 32 to propel the piston 30 back and forth in the cylinder 50. The movement of the piston 30 and piston rod 32 in the cylinder 50 is dependent on the direction of

movement of the rotor 12 and linkages 14 and the particular configuration of the connecting mechanism 20. The use of the connecting mechanism 20 defines a positive, controlled and predetermined travel path for the piston rod 32 and piston 30, thereby preventing the overextension or underextension of the piston 30 during certain loading conditions of the compressor.

[0018] As shown in Figure 2, a gear-type mechanism 120 is used to connect the linear motor 10 and the piston rod(s) 32. The mechanism 120 includes a linear gear 22 that is connected to and driven by the linkage 14 that is driven by the rotor 12. The liner gear 22 preferably includes opposed first and second gear surfaces 24, 26. Preferably, each gear surface 24, 26 is substantially parallel with the longitudinal axis of the linear gear 22. The gear surface 24, 26 may be any suitable gear surface type, such as square-toothed, grooved, or serrated. As shown in Figure 2, each gear surface 24, 26 contacts a connecting gear 28 that is connected to a corresponding piston rod 32. Each connecting gear 28 is shaped so as to smoothly engage the gear surface 24, 26 to drive the connecting rod 32 with a minimum of energy loss, and to provide a pre-determined and controlled travel path for the piston rod 32 and piston 30. Preferably, the travel path includes predetermined top-dead center piston position and bottom-dead center piston position which remain constant despite load increases and decreases. In an alternative embodiment not illustrated, a single gear surface is provided on the linear gear, with a plurality of connecting gears aligned such that each connecting gear is in contact with the gear surface, each connecting gear driving a corresponding piston rod to propel a corresponding piston.

[0019] As shown in Figure 3, a track-type mechanism 220 is used to connect the linear motor 10 and piston rod(s) 32. The mechanism 220 includes a drive block 60 having an embedded track 62 for receiving a drive pin 64. The drive pin 64 is connected to the linkage 14 that is in turn driven by the rotor 12. The drive pin 64 is also connected to one or more piston rods 32. As the rotor 12 drives the linkage 14, the drive pin 64 is moved in the track 62. As the drive pin 64 moves, it pushes the piston rod 32 to force the piston 30 to move in the cylinder 50. The track 62 is shaped and sloped so as to smoothly engage the piston connecting rod 32 to drive the piston 30 up and down in the cylinder 50 with a minimum of energy loss, and to

provide a pre-determined and controlled travel path for the piston rod 32 and piston 30. Preferably, the travel path includes predetermined top-dead center piston position and bottom-dead center piston position which remain constant despite load increases and decreases. In the embodiment of Figure 3, these positions are accomplished by the inclusion of substantially horizontal, non-sloped track sections 66 at each end of the track 62. When the drive pin 64 enters a horizontal section 66, the position of the connecting rod 32 remains substantially vertically constant, so that the piston 30 is neither driven up nor pulled down until the pin is pulled or pushed back into the sloped portion of the track by the linkage 14. Preferably, as shown in Figure 3, more than one piston rod 32 is connected to the drive pin 64 so that reciprocating opposed pistons 30 can be driven as the pin 64 moves throughout the track 62.

[0020] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.